

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

(NASA-CR-161125) TRANSISTOR STEP STRESS
PROGRAM FOR JANTX2N4150 Final Report (DCA
Reliability Lab., Sunnyvale, Calif.) 39 p
HC A03/MF A01 CSCI 09A

N79-18204

G3/33 14159
Unclass

TRANSISTOR STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR
JANTX 2N4150

FEBRUARY 1979

Prepared
For

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Marshall Space Flight Center, Alabama 35812

DCA RELIABILITY LABORATORY
SPECIAL PRODUCTS DIVISION
975 BENICIA AVE
SUNNYVALE, CALIFORNIA 94086





FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.



TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 TEST REQUIREMENTS	1
2.1 Electrical	1
2.2 Stress Circuit	1
2.3 Group I - Power Stress	2
2.4 Group II - Temperature Stress I	2
2.5 Group III - Temperature Stress II	2
3.0 DISCUSSION OF TEST RESULTS	3
3.1 Group I - Power Stress	3
3.1.1 General Semiconductor, Inc.	3
3.1.2 Transitron	4
3.1.3 Statistical Summary - Group I	5
3.2 Group II - Temperature Stress I	5
3.2.1 General Semiconductor, Inc.	5
3.2.2 Transitron	6
3.2.3 Statistical Summary - Group II	7
3.3 Group III - Temperature Stress II	7
3.3.1 General Semiconductor, Inc.	7
3.3.2 Transitron	8
3.3.3 Statistical Summary - Group III	9
4.0 FINAL DATA SUMMARY	9
5.0 CONCLUSIONS	10



LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1	Power and Temperature Stress Circuit for JANTX2N4150	13
2	Cumulative Percent Failures Versus Junction Temperature, General Semiconductor	14
3	Time Steps Versus Junction Temperature, General Semiconductor	15
4	Cumulative Percent Failures Versus Junction Temperature, Transitron	16
5	Time Steps Versus Junction Temperature, Transitron	17
A-1	S/N 9421. Magnification 29X	32
A-2	S/N 9428. Magnification 400X	32
A-3	S/N 9468. Magnification 80X	33
A-4	S/N 9480. Magnification 29X	33



LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
1	Test Flow Diagram	18
2	Parameters and Test Conditions	19
3	Power Stress Burn-In Conditions	19
4	Group I - Power Stress Data Summary	21
5	Group II - Temperature Stress I Data Summary	23
6	Group III - Temperature Stress II Data Summary	24
7	Final Data Summary	25
8	Step Stress Catastrophic Failure Summary	26
9	Step Stress Parametric Failure Summary	27



1.0 INTRODUCTION

DCA Reliability Laboratory, under Contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the transistor JANTX2N4150 manufactured by General Semiconductor and Transistron.

A total of 47 samples from General Semiconductor and 48 from Transistron were submitted to the process outlined in Table 1. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 High-Speed Computer-Controlled Tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit shown in Figure 1 was used to power all the test devices during the power/temperature stress conditions. The current was set by I_E and the voltage was varied in order to comply with the specified power rating for this device. At least one of the devices was subjected to Maximum



Rated Power (MRP). All remaining devices were subjected to no less than 90% of MRP. See Figure 1 for load resistance values and voltages.

2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the Power Stress Process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent of maximum rated power (MRP) for 2500 hours or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1. (*See Notes at end of text.)

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I Process. Group II was subjected to 1600 hours of stress at maximum rated power in increments of 160 hours. The temperature was increased in steps of 25°C, commencing at 75°C and terminating at 300°C or until 50% or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-one units, 15 from General Semiconductor and 16 from Transitron, were submitted to the Temperature Stress II Process. Group III was subjected to 112 hours of stress at maximum rated power in increments of 16 hours. The temperature was increased in steps of 25°C, commencing at



150°C and terminating at 300°C or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 General Semiconductor, Inc. The GSI sample lot completed 1500 hours of Group I Testing before the lot was stopped because 50% of the lot had failed. The first catastrophic failures occurred 10 hours into the 125% MRP step. Serial numbers 9423, 9426 and 9428 failed due to excessive I_{CBO} leakage. The next failures occurred 50 hours into the 125% MRP step. Serial number 9421 failed the maximum $V_{CE(SAT)}$ limit. Serial number 9416 was removed from testing as a MIL-S-19500 failure. The next catastrophic failure occurred 250 hours into the 125% MRP step. Serial number 9427 failed due to excessive I_{CBO} leakage. The last failures occurred 500 hours into the 125% MRP step. Serial numbers 9414, 9417 and 9419 failed due to excessive I_{CBO} leakage. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 21.34 μ A from an initial mean of 15.57nA to a final mean of 21.36 μ A.
- 2) The mean value for $V_{CE(SAT)1}$ changed 8.500mV from an initial mean of 431.1mV to a final mean of 422.6mV.
- 3) The mean value for $V_{CE(SAT)2}$



changed 17.80mV from an initial mean of 856.0mV to a final mean of 838.2mV.

4) The mean value for h_{FE} changed 16.00 from an initial mean of 127.7 to a final mean of 143.7.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.2 Transitron. The Transitron sample lot completed the entire 2500 hours of Group I Testing with a total of seven catastrophic failure. The first failure occurred 50 hours into the 125% MRP step. Serial number 9468 failed the maximum $V_{CE(SAT)1}$ limit. The next failures occurred 150 hours into the 150% MRP step. Serial numbers 9471 and 9472 failed due to excessive I_{CBO} leakage. The next failure occurred 250 hours into the 150% MRP step. Serial number 9480 failed due to excessive I_{CBO} leakage. The next failures occurred 10 hours into the 175% MRP step. Serial number 9476 failed the maximum I_{CBO} and minimum h_{FE} limits. Serial number 9477 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ limits. The last failure occurred 25 hours into the 175% MRP step. Serial number 9469 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 391.7nA from an initial mean of 2.854nA to a final mean of 394.6nA.
- 2) The mean value for $V_{CE(SAT)1}$ changed 118.9mV from an initial mean of 336.8mV to a final mean of 455.7mV.
- 3) The mean value for $V_{CE(SAT)2}$ changed 258.0mV from an initial mean of 676.3mV to



a final mean of 934.3mV.

4) The mean value for h_{FE} changed 2.500 from an initial mean of 130.3 to a final mean of 132.8.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.3 Statistical Summary - Group I. Table 4 outlines the results of Group I - Power Stress Process for each of the electrical parameters and all measurement points for both GSI and Transatron.

3.2 Group II - Temperature Stress I

3.2.1 General Semiconductor, Inc. The GSI sample lot completed the entire 1600-hour Group II Testing with a total of six catastrophic failures. At 160 hours into the 75°C-temperature step, serial number 9435 was removed from testing as a MIL-S-19500 failure. The first catastrophic failure occurred 160 hours into the 100°C-temperature step. Serial number 9499 failed the minimum h_{FE} limit. The next failure occurred 160 hours into the 150°C-temperature step. Serial number 9437 failed due to excessive I_{CBO} leakage. The next failure occurred 160 hours into the 200°C-temperature step. Serial number 9433 failed the minimum h_{FE} limit. Also at this point in time, serial number 9434 was removed from testing as a MIL-S-19500 failure. The next failures occurred 160 hours into the 225°C-temperature step. Serial number 9430 failed due to excessive I_{CBO} leakage. The last failures occurred 160 hours into the 275°C-temperature step. Serial numbers 9439



and 9442 failed due to excessive I_R leakage. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 6.428 μA from an initial mean of 265.3nA to a final mean of 6.693 μA .
- 2) The mean value for $V_{CE(SAT)1}$ changed 11.80mV from an initial mean of 447.7mV to a final mean of 459.5mV.
- 3) The mean value for $V_{CE(SAT)2}$ changed 6.400mV from an initial mean of 908.1mV to a final mean of 914.5mV.
- 3) The mean value for h_{FE} changed 108.8 from an initial mean of 369.7 to a final mean of 260.9.
- 4) The mean value for h_{FE} changed 11.70 from an initial mean of 107.6 to a final mean of 119.3.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.2 Transitron. The Transitron sample lot completed the entire 1600-hour Group II Testing with only one catastrophic failures. The failure occurred 160 hours into the 300°C-temperature step. Serial number 9488 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. At this point in time, serial numbers 9486, 9493 and 9495 were removed as visual rejects due to handling. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 396.3nA from an initial mean of 4.851nA to a final mean of 401.2nA.



- 2) The mean value for $V_{CE(SAT)1}$ changed 750.9mV from an initial mean of 346.1mV to a final mean of 1.097V.
- 3) The mean value for $V_{CE(SAT)2}$ changed 636.5mV from an initial mean of 825.5mV to a final mean of 1.462V.
- 4) The mean value for h_{FE} changed 14.08 from an initial mean of 103.2 to a final mean of 89.12.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.3 Statistical Summary - Group II. Table 5 of this report outlines the results of Group II - Temperature Stress I Testing, for each of the electrical parameters and all of the measurement points pertaining to both General Semiconductor, Inc. and Transistron.

3.3 Group III - Temperature Stress II

3.3.1 General Semiconductor, Inc. The GSI sample lot completed the entire 112-hour Group III Testing with a total of seven catastrophic failures. The first failure occurred 16 hours into the 150°C-temperature step. Serial number 9455 failed due to excessive I_{CBO} leakage. The next failures occurred 16 hours into the 175°C-temperature step. Serial numbers 9454 and 9458 failed due to excessive I_{CBO} leakage. The next failures occurred 16 hours into the 200°C-temperature step. Serial numbers 9449 and 9451 failed due to excessive I_{CBO} leakage. The next failure occurred 16 hours into the 225°C-temperature step. Serial number 9444



failed due to excessive I_R leakage. The last failure occurred 16 hours into the 300°C-temperature step. Serial number 9443 failed due to excessive I_{CBO} leakage. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 2.885 μA from an initial mean of 45.74 nA to a final mean of 2.931 μA .
- 2) The mean value for $V_{CE(SAT)1}$ changed 1.800 mV from an initial mean of 479.6 mV to a final mean of 481.4 mV.
- 3) The mean value for $V_{CE(SAT)2}$ changed 6.000 mV from an initial mean of 983.4 mV to a final mean of 989.4 mV.
- 4) The mean value for h_{FE} changed 3.7 from an initial mean of 108.3 to a final mean of 112.0.

The control units for this sample lot remained constant throughout the entire Group IV Testing.

3.3.2 Transitron. The Transitron sample lot completed the entire 112-hour Group III Testing with one catastrophic failure. The failure occurred 16 hours into the 225°C-temperature step. Serial number 9499 failed the maximum $V_{CE(SAT)1}$ limit. Serial number 9506 was removed 16 hours into the 275°C-temperature step as a visual reject due to handling. Typical characteristics of this sample lot's performance were:

- 1) The mean value for I_{CBO} changed 15.70 nA from an initial mean of 1.665 nA to a final mean of 17.36 nA.
- 2) The mean value for $V_{CE(SAT)1}$ changed 0.600 mV from an initial mean of



398.8mV to a final mean of 399.4mV.

2) The mean value for $V_{CE(SAT)}$ changed 12.30mV from an initial mean of 847.3mV to a final mean of 835.0mV.

4) The mean value for h_{FE} changed 0.100 from an initial mean of 112.9 to a final mean of 112.8.

The control units for this sample lot remained constant throughout the entire Group III Testing.

3.3.3 Statistical Summary - Group III. Table 6 outlines the results of Group III - Temperature Stress II Testing, for each of the four electrical parameters and all of the measurement points for both General Semiconductor, Inc. and Transitron.

4.0 FINAL DATA SUMMARY

Table 7 statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables 8 and 9 summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table 8 and parametric failures in Table 9. The data from Table 8 were used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in Figures 3 and 5, respectively.



Junction temperature is plotted on an inverse hyperbolic scale.

5.0

CONCLUSIONS

An overall look at all three stress tests reveals that the Transitron device out-performed the General Semiconductor, Inc. device.

In the Group I Testing, the General Semiconductor sample lot had to be stopped 500 hours into the 125% MRP step, whereas the Transitron lot completed the entire testing with a total of seven failures. In the Group II and III Testings, Transitron experienced one catastrophic failure in each test and General Semiconductor experienced six and seven, respectively.

The General Semiconductor samples had surface inversions and leakage due to contamination. Bare junction areas and the extremely high temperature contributed to the contamination vulnerability of these devices. There is a voltage threshold on these devices where the inversion and drift of I_{CBO} is triggered. Once begun, the leakage continues to increase over many seconds.

One Transitron failure had low resistance contacts to emitter, collector and base. This suggests that changes in the bulk silicon such as an increase in base resistivity caused by migration of gold under the heat and bias of the stress test was the cause.

A plot showing cumulative failure distribution for Group II was drawn for the General Semiconductor



sample lot (Figures 2 and 3), but a complete plot could not be drawn due to an early excessive freak failure rate in the Group III Testing. A complete plot could not be drawn for the Transistron sample lot (Figures 4 and 5) due to an insufficient number of main failure points in both the Group II and III Testings.

A broken circle around a marked point on the graph indicates a freak failure not calculated as part of the regression line. A solid circle around a marked point indicates an isolated main failure point. The regression line was calculated using the least squares method.

The activation energy was calculated from the formula:

$$E = \left[\ln \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^\circ\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{ eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.
 t_2 = step of Group III - Temp Stress II = 16 hrs.
 T_1 = temperature in $^\circ\text{C}$ of 16% failure for Group II.
 T_2 = temperature in $^\circ\text{C}$ of 16% failure for Group III.



JANTX2N4150

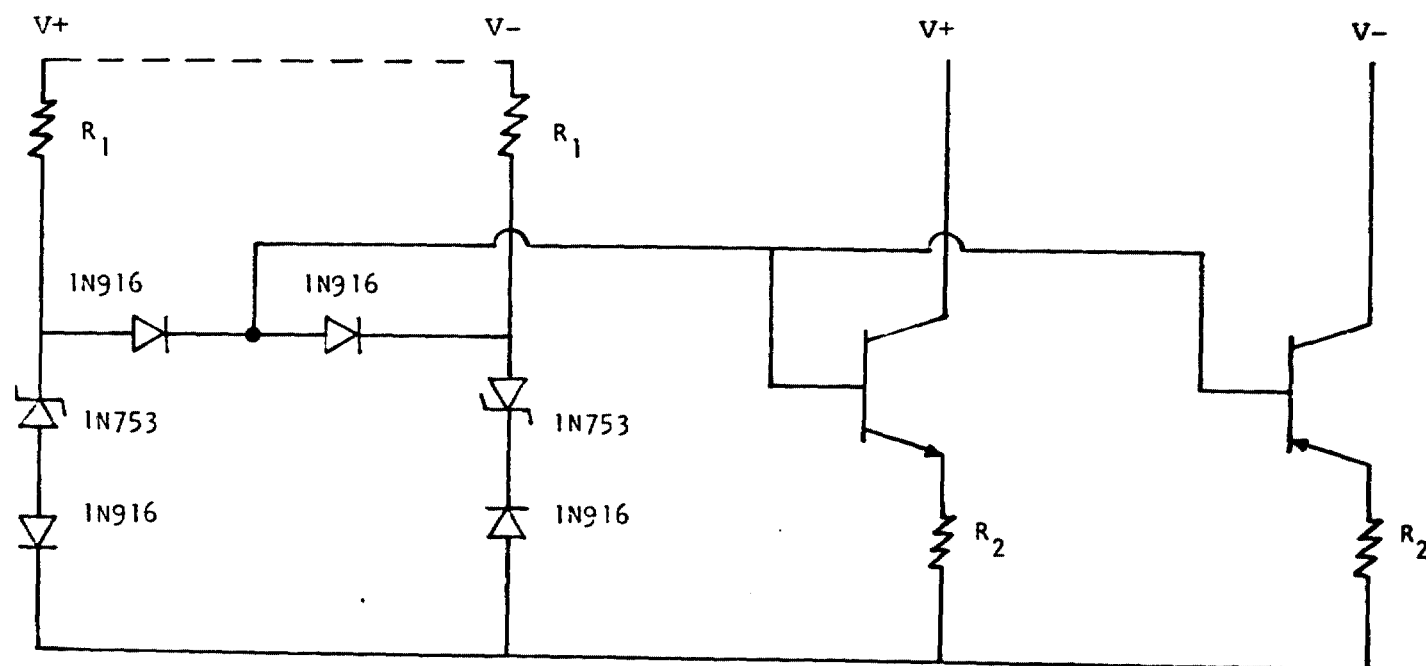
NOTE:

*** Conditions for failure:**

- A) Open or short
- B) Leakage exceeds the maximum limit by 100 times.
- C) Other parameters exceed MIL limits by 50% or more.



TRANSISTORS



$$R_1 = 800 \pm 5\%, 2W$$

$$R_2 = \text{Individual Part Type Calculation; } R_2 = 5.2V/I_E \pm 5\%; R_2 = 27.5\Omega \pm 1\%, 3W$$

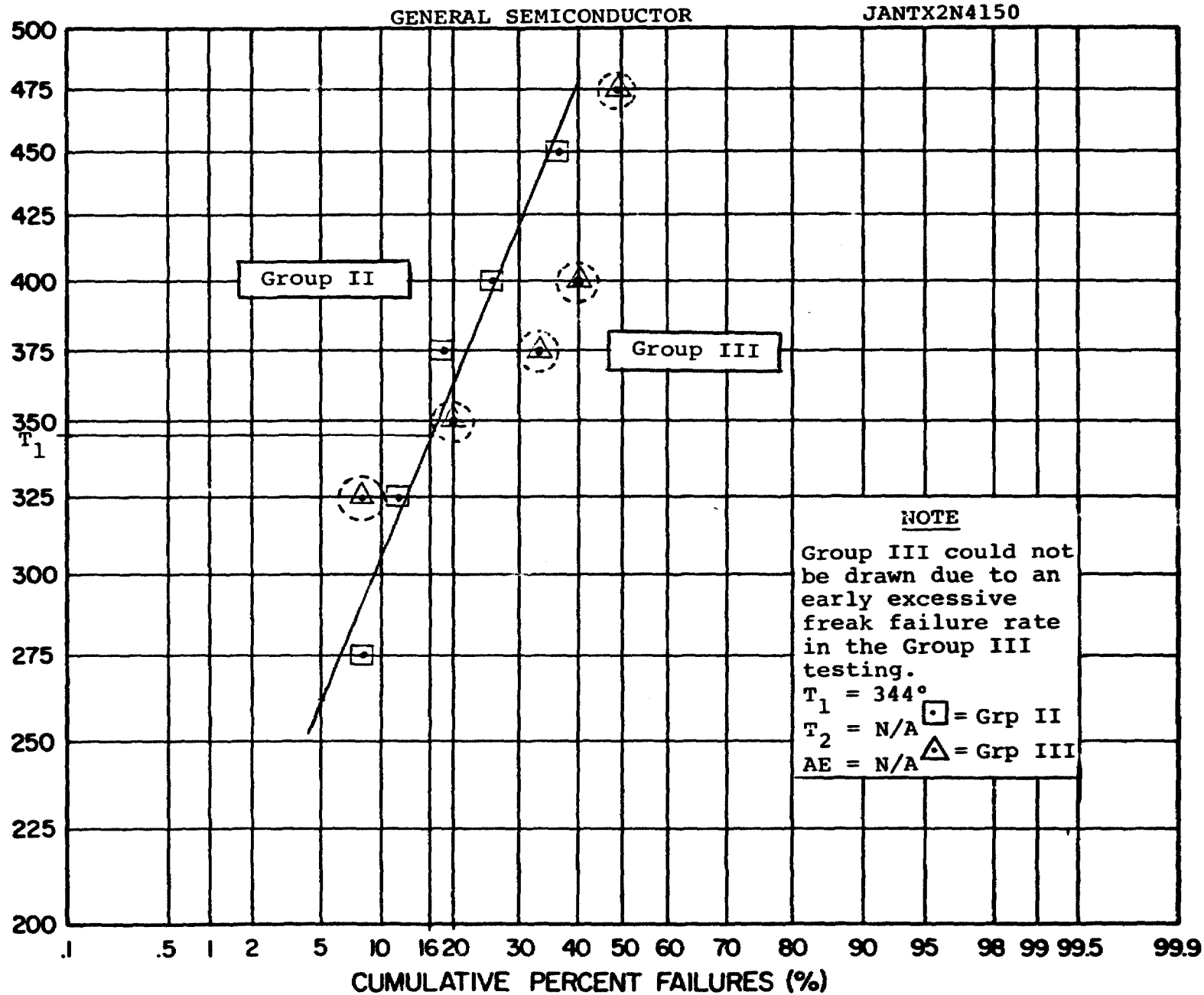
V+ for NPN Transistors

V- for PNP Transistors

FIGURE 1
Power/Temperature Stress Circuit for JANTX2N4150



* JUNCTION TEMPERATURE (°C)



JANTX2N4150

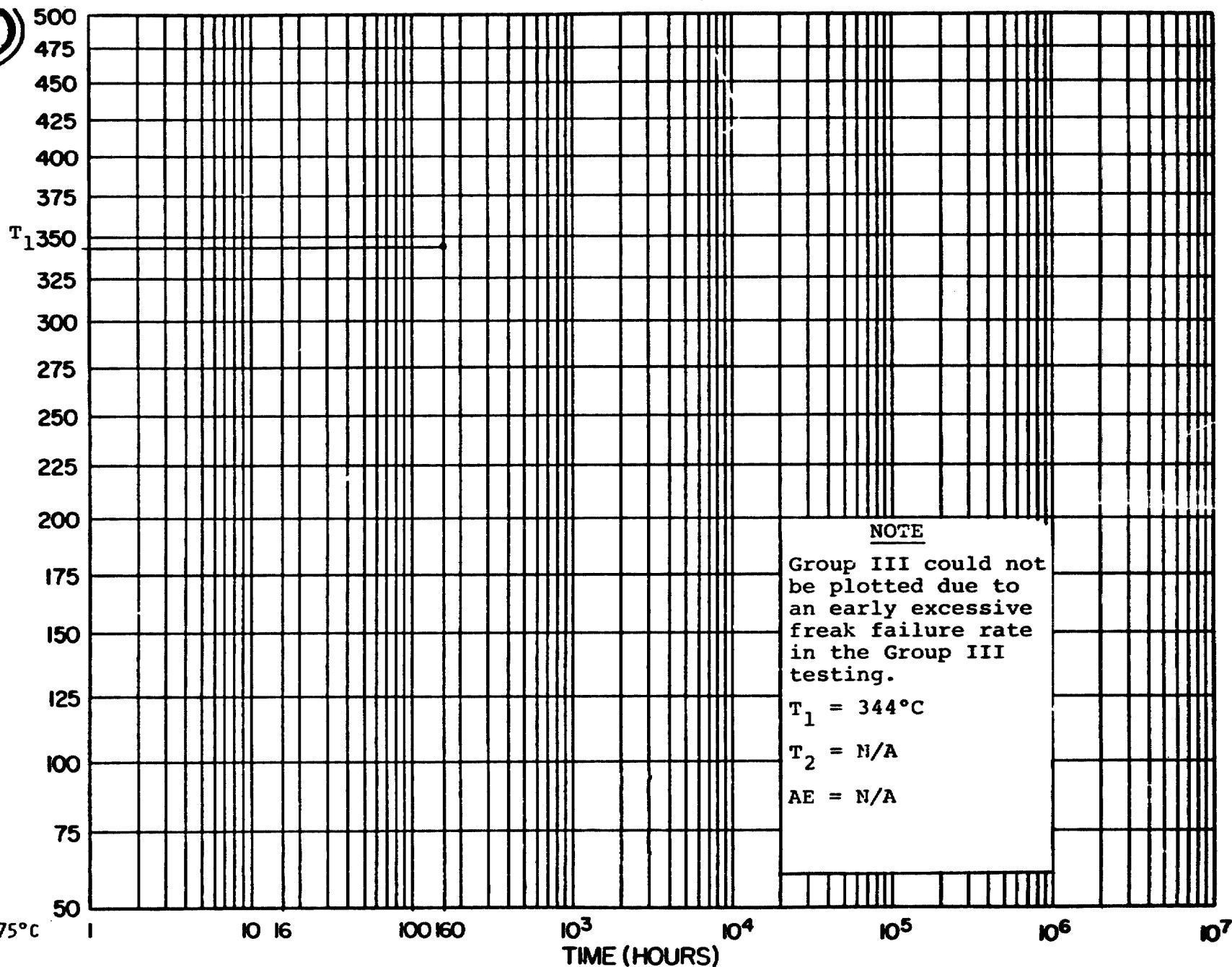
FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, General Semiconductor



15

* JUNCTION TEMPERATURE (°C)



JANTX2N4150

FIGURE 3
Time Steps Versus Junction Temperature, General Semiconductor

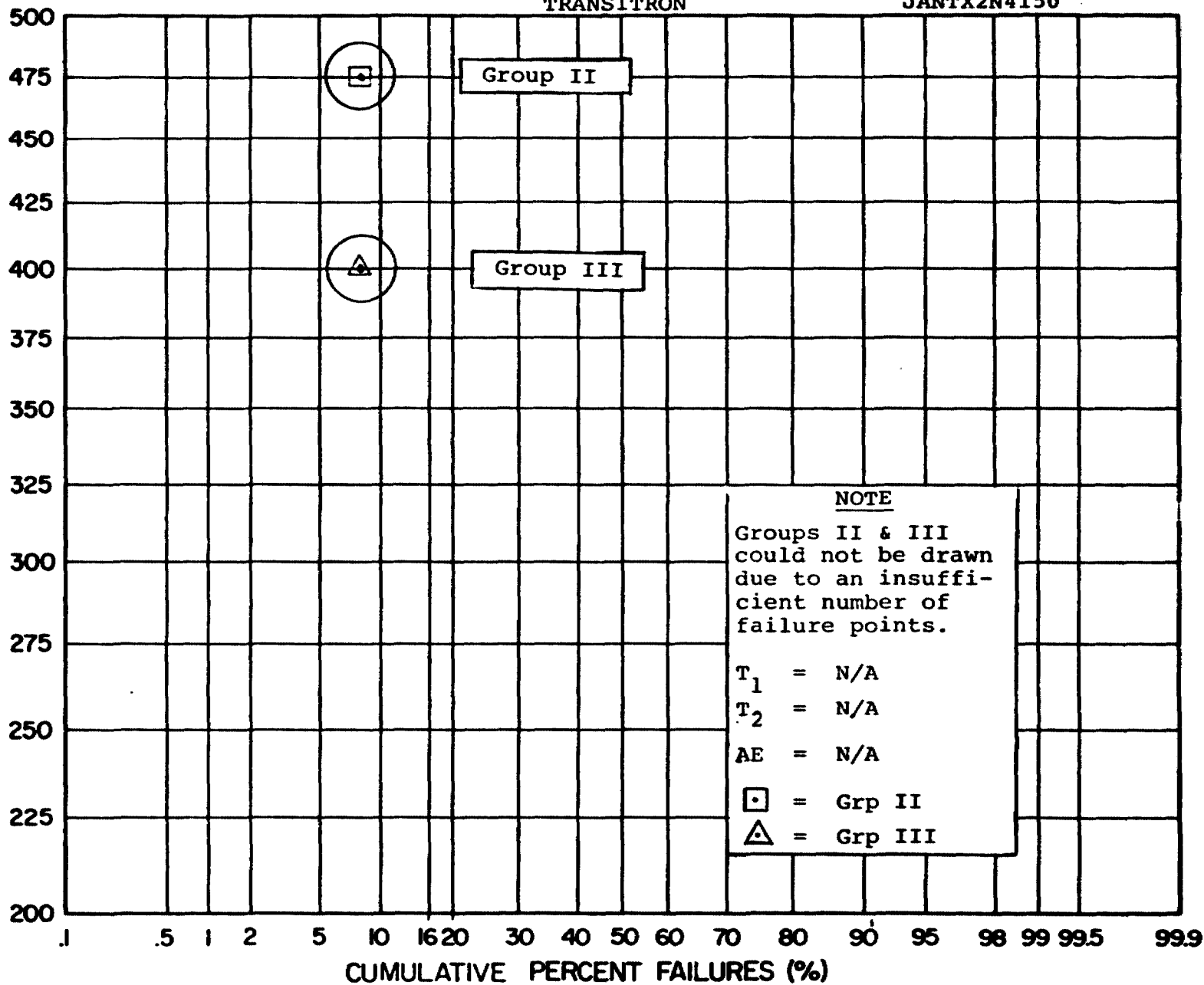


16

* JUNCTION TEMPERATURE (°C)

TRANSITRON

JANTX2N4150



*NOTE

$$T_J \approx T_A + 175^\circ\text{C}$$

CUMULATIVE PERCENT FAILURES (%)

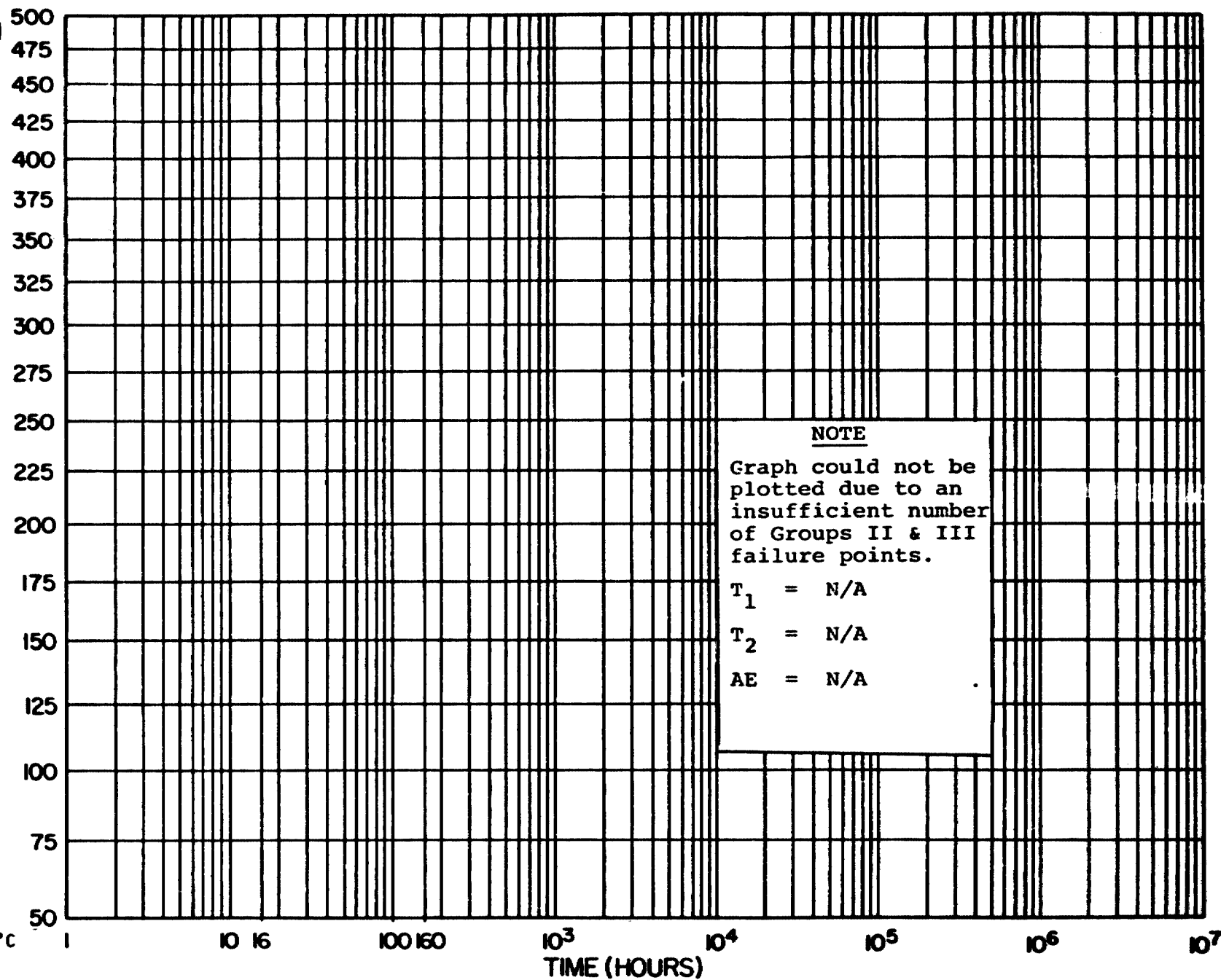
FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Transitron

JANTX2N4150



* JUNCTION TEMPERATURE (°C)



*NOTE

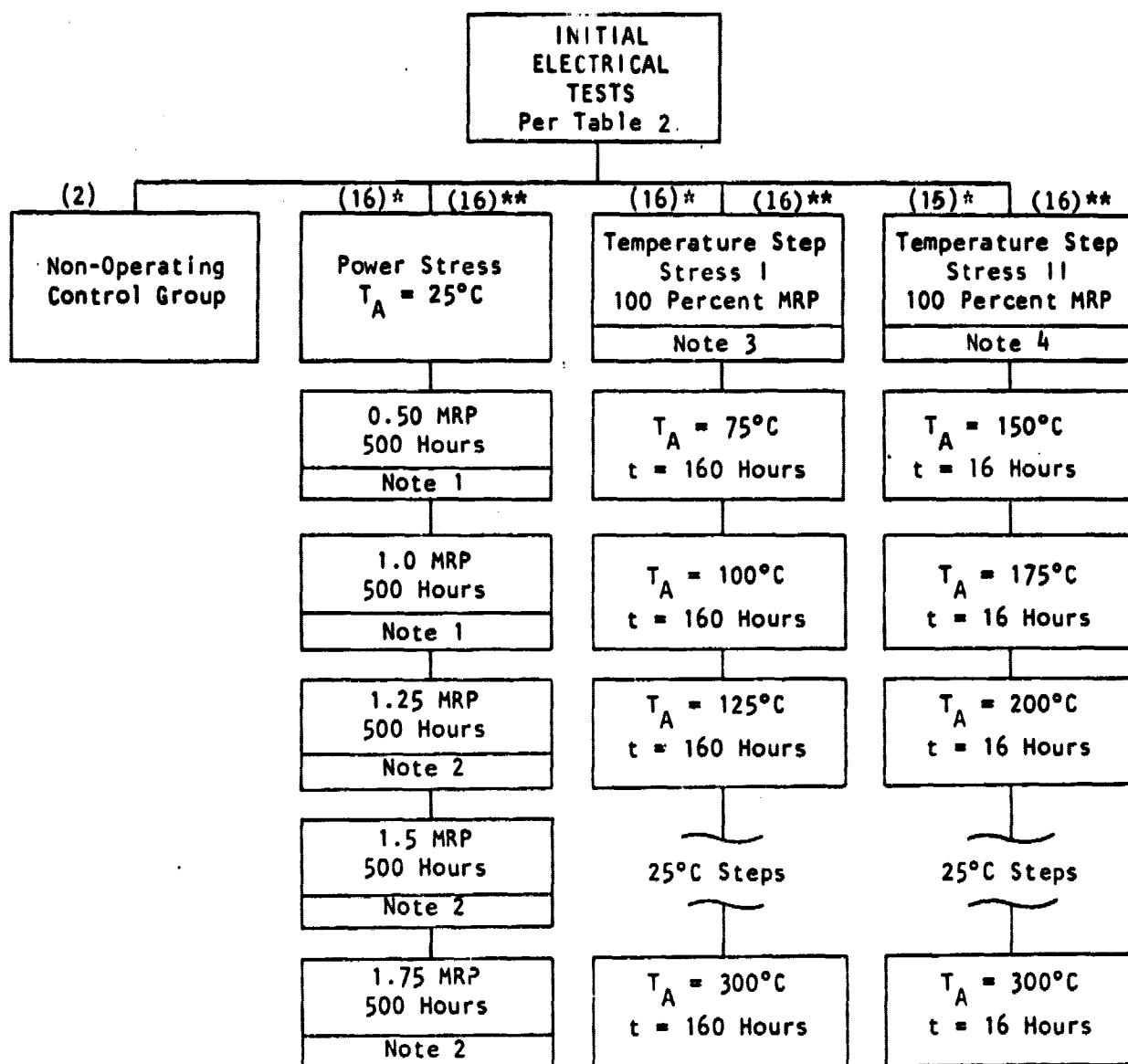
$$T_J \approx T_A + 175^\circ\text{C}$$

TIME (HOURS)

FIGURE 5

Time Steps Versus Junction Temperature, Transistron

JANTX2N4150

TABLE 1
TEST FLOW DIAGRAM

Quantity per manufacturer (*General Semiconductor, Inc)
(**Transitron)

NOTES:

- 1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
- 2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
- 3) Electrical measurements per Table 2 were made at the end of each 160 hours.
- 4) Electrical measurements per Table 2 were made at the end of each 16 hours.



TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_{CBO}	@ $V_{CB} = 80V$	-	.1	-	10	μA
$V_{CE(SAT) 1}$	@ $I_C = 5A$ $I_B = .5A$ (Pulsed)	-	.6	-	.9	V
$V_{CE(SAT) 2}$	@ $I_C = 10A$ $I_B = 1A$ (Pulsed)	-	2.5	-	3.75	V
h_{FE}	@ $V_{CE} = 5V$ $I_C = 1A$ (Pulsed)	50	900	25	1350	-

NOTES:

1/ In addition, any -pen or short short shall be considered catastrophic

TABLE 3
POWER STRESS BURN-IN CONDITIONS

$I_E = 200mA$	
$V_{CE} =$	Percent P_D
3.75V	50
7.50V	100
9.4V	125
11.25V	150
13.1V	175



NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of $\pm 1\%$ of the reading and $\pm$ one digit except for readings greater than 9.99mA which have an absolute accuracy of $\pm 2\%$ of the reading and $\pm$ one digit. The data also have a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.

TABLE 4
GROUP I - POWER STRESS DATA SUMMARY

Page 1 of 2

PARAMETER	$I_{CBO} = .1\mu A(\text{MAX})$		$V_{CE(\text{SAT})1} = .6V(\text{MAX})$		$V_{CE(\text{SAT})2} = 2.5V(\text{MAX})$		$h_{FE} = 50(\text{MIN}), 900(\text{MAX})$	
CONDITIONS AND LIMIT	@ $V_{CB} = 80V$		@ $I_C = 5A$ $I_B = .5A$ (Pulsed)		@ $I_C = 10A$ $I_B = 1.A$ (Pulsed)		@ $V_{CE} = 5V$ $I_C = 1A$ (Pulsed)	
IDENTIFICATION	GST	TRN	GSI	TRN	GSI	TRN	GSI	TRN
INITIAL DATA								
MIN VALUE	970.0pA	700.0pA	370.0mV	288.0mV	778.0mV	556.0mV	73.50	61.30
MAX VALUE	136.0nA	17.40nA	487.0mV	395.0mV	989.0mV	788.0mV	214.0	160.0
MEAN	15.57nA	2.854nA	431.1mV	336.8mV	856.0mV	676.3mV	127.7	130.3
STD DEV	31.81nA	3.904nA	28.62mV	36.10mV	64.03mV	74.58mV	42.47	29.80
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 HRS	43.47nA	9.000pA	6.300mV	3.500mV	4.000mV	1.500mV	7.500	-1.400
150 HRS	3.540nA	52.00pA	2.300mV	4.300mV	7.100mV	1.500mV	7.200	-0.800
250 HRS	-1.370nA	-50.00pA	1.500mV	-2.600mV	3.200mV	-2.300mV	10.10	-1.200
500 HRS	9.250nA	-696.0pA	8.200mV	4.500mV	6.000mV	-5.000mV	8.300	-5.800
100% POWER								
550 HRS	38.07nA	-388.0pA	4.600mV	2.900mV	4.100mV	-4.000mV	9.400	-1.700
650 HRS	60.81nA	-428.0pA	4.200mV	3.700mV	6.100mV	-0.200mV	8.100	-1.700
750 HRS	136.7nA	-466.0pA	7.700mV	5.400mV	-0.400mV	-5.000mV	7.900	-1.300
1000 HRS	139.8nA	-48.00pA	7.600mV	8.500mV	9.900mV	-3.700mV	7.800	-0.700
125% POWER								
1010 HRS	*15.82μA	3.713nA	2.300mV	3.600mV	3.100mV	2.900mV	6.700	-1.300
1025 HRS	107.0nA	7.007nA	-29.20mV	7.900mV	-16.40mV	-3.400mV	11.50	-3.600
1050 HRS	*905.0nA	170.0pA	1.100mV	*44.50mV	-16.10mV	50.70mV	12.70	2.200
1150 HRS	700.9nA	6.523nA	-3.100mV	5.300mV	-14.70mV	11.00mV	19.00	-6.300
1250 HRS	*1.726μA	741.0pA	2.000mV	4.300mV	-12.80mV	10.30mV	21.10	-2.100
1500 HRS	*21.34μA	2.241nA	-8.500mV	-1.700mV	-17.80mV	-1.000mV	16.00	-1.800

(continued on second sheet)



TABLE 4 (Cont'd)

(continued from first sheet)

GROUP I

- POWER STRESS DATA SUMMARY

Page 2 of 2

PARAMETER	$I_{CBO} = .1\mu A(\text{MAX})$		$V_{CE(\text{SAT})1} = .6V(\text{MAX})$		$V_{CE(\text{SAT})2} = 2.5V(\text{MAX})$		$h_{FE} = 50(\text{MIN}), 900(\text{MAX})$	
CONDITIONS AND LIMITS	@ $V_{CB} = 80V$		@ $I_C = 5A; I_B = .5A(\text{Pulsed})$		@ $I_C = 10A; I_B = 1A(\text{Pulsed})$		@ $V_{CE} = 5V; I_C = 1A(\text{Pulsed})$	
IDENTIFICATION	GSI	TRN	GSI	TRN	GSI	TRN	GSI	TRN
INITIAL DATA								
MIN VALUE	970.0pA	700.0pA	374.0mV	288.0mV	778.0mV	556.0mV	73.50	61.30
MAX VALUE	136.0nA	17.40nA	487.0mV	395.0mV	989.0mV	788.0mV	214.0	160.0
MEAN	15.57nA	2.854nA	431.1mV	336.8mV	856.0mV	676.3mV	127.7	130.3
STD DEV	31.81nA	3.904nA	28.62mV	36.10mV	64.03mV	74.58mV	42.47	29.80
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 HRS	JOB STOPPED	39.70nA	JOB STOPPED	-0.900mV	JOB STOPPED	7.400mV	JOB STOPPED	-2.500
1525 HRS		44.98nA		-1.200mV		8.000mV		-0.900
1550 HRS		244.2nA		12.10mV		29.50mV		0.000
1650 HRS		*1.401μA		13.00mV		35.10mV		0.700
1750 HRS		*811.2nA		12.80mV		28.30mV		-8.200
2000 HRS		816.4nA		42.00mV		128.0mV		-9.300
175% POWER								
2010 HRS		*1.629μA		*72.20mV		*711.7mV		63.70
2025 HRS		898.7nA		81.90mV		789.7mV		*39.00
2050 HRS		81.55nA		13.00mV		24.50mV		-4.900
2150 HRS		199.2nA		20.60mV		35.60mV		-5.400
2250 HRS		343.7nA		15.10mV		35.30mV		-8.200
2500 HRS		391.7nA		118.9mV		258.0mV		2.500
FINAL DATA								
MIN VALUE	2.060nA	1.400nA	389.0mV	371.0mV	775.0mV	752.0mV	93.10	66.20
MAX VALUE	99.90μA	3.200μA	463.0mV	680.0mV	986.0mV	1.460V	206.0	181.0
MEAN	21.36μA	394.6nA	422.6mV	455.7mV	838.2mV	934.3mV	143.7	132.8
STD DEV	39.47μA	995.1nA	22.70mV	88.69mV	64.17mV	213.5mV	39.79	28.78

* NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT

TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY

PARAMETERS	$I_{CBO} = .1\mu A$ (MAX)		$V_{CE(SAT)1} = .6V$ (MAX)		$V_{CE(SAT)2} = 2.5V$ (MAX)		$h_{FE}=50(MIN), 900(MAX)$	
CONDITIONS AND LIMITS	@ $V_{CB} = 80V$		@ $I_C=5A; I_B=.5A(Pulsed)$		@ $I_C=10A; I_B=1A(Pulsed)$		@ $V_{CE}=5V; I_C=1A(Pulsed)$	
IDENTIFICATION	GS1	TRN	GS1	TRN	GS1	TRN	GS1	TRN
INITIAL DATA								
MIN VALUE	700.0pA	90.0pA	389.0mV	311.0mV	742.0mV	600.0mV	66.00	62.50
MAX VALUE	4.050 μA	21.30nA	510.0mV	378.0mV	1.380V	1.440V	142.0	168.0
MEAN	165.3nA	4.851nA	447.7mV	346.1mV	908.1mV	825.5mV	107.6	103.2
STD DEV	5.630nA	6.294nA	32.56mV	20.39mV	142.6mV	227.7mV	24.12	33.23
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS TEMP (T_A)								
160 75°C	-47.80nA	26.00pA	-2.000mV	-1.400mV	-0.600mV	2.900mV	-1.900	-1.600
320 100°C	-22.40nA	206.0pA	-4.600mV	-1.000mV	-1.600mV	-3.700mV	*-9.240	-2.600
480 125°C	919.7nA	-502.0pA	-2.900mV	-0.500mV	-1.200mV	4.100mV	-1.400	-2.300
640 150°C	*13.31 μA	1.403nA	-2.500mV	0.000mV	-9.800mV	0.200mV	1.200	-1.600
800 175°C	-242.1nA	582.0pA	2.900mV	0.100mV	-2.500mV	-1.600mV	-0.900	1.300
960 200°C	-239.8nA	-245.0pA	-3.800mV	-2.200mV	-9.400mV	-14.10mV	2.700	-0.900
1120 225°C	*1.278 μA	1.159nA	2.200mV	-1.300mV	0.900mV	-15.10mV	8.600	0.500
1280 250°C	*1.529 μA	2.631nA	4.400mV	-0.700mV	4.100mV	-13.20mV	7.900	0.500
1440 275°C	*2.979 μA	456.0pA	2.700mV	-4.300mV	-2.800mV	-9.700mV	7.600	-2.100
1600 300°C	6.428 μA	*396.3nA	11.80mV	-750.9mV	6.400mV	636.5mV	11.70	-14.08
FINAL DATA								
FINAL TEMP	300°C	300°C	300°C	300°C	300°C	300°C	300°C	300°C
MIN VALUE	410.0pA	490.0pA	404.0mV	315.0mV	798.0mV	607.0mV	79.40	1.700
MAX VALUE	66.70 μA	5.110 μA	517.0mV	9.990V	1.110V	9.990V	156.0	128.0
MEAN	6.693 μA	401.2nA	409.5mV	1.097V	914.5mV	1.462V	119.3	89.12
STD DEV	19.07 μA	1.359 μA	32.16mV	2.567V	99.59mV	2.456V	28.52	34.68

* NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT

TABLE 6

JANTX2N4150

GROUP III TEMP STRESS II DATA SUMMARY

PARAMETERS	$I_{CBO} = .1\mu A$ (MAX)		$V_{CE(SAT)1} = .6V$ (MAX)		$V_{CE(SAT)2} = 2.5V$ (MAX)		$h_{FE} = 50$ (MIN), 900 (MAX)	
CONDITIONS AND LIMITS	@ $V_{CB} = 80V$		@ $I_C = 5A$; $I_B = .5A$ (Pulsed)		@ $I_C = 10A$; $I_B = 1A$ (Pulsed)		@ $V_{CE} = 5V$; $I_C = 1A$ (Pulsed)	
IDENTIFICATION	GSI	TRN	GSI	TRN	GSI	TRN	GSI	TRN
INITIAL DATA								
MIN VALUE	640.0pA	420.0pA	404.0mV	322.0mV	798.0mV	621.0mV	75.80	56.70
MAX VALUE	459.0nA	17.60nA	520.0mV	595.0mV	1.240V	1.250mV	175.0	150.0
MEAN	45.74nA	1.665nA	479.6mV	398.8mV	983.4mV	847.3mV	108.3	112.9
STD DEV	111.6nA	4.117nA	30.42mV	65.20mV	107.1mV	167.5mV	26.49	28.77
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS TEMP (T_A)								
16 150°C	*4.855 μA	231.0pA	0.300mV	0.100mV	1.200mV	1.000mV	3.000	0.600
32 175°C	*5.234 μA	483.0pA	-2.700mV	0.800mV	-5.300mV	0.500mV	6.700	2.500
48 200°C	*3.529 μA	629.0pA	1.200mV	15.30mV	-1.100mV	33.00mV	4.700	2.900
64 225°C	*1.722 μA	837.0pA	3.200mV	*98.30mV	12.20mV	168.7mV	6.500	2.700
80 250°C	49.60nA	-574.0pA	2.000mV	2.500mV	9.400mV	23.20mV	-3.800	1.400
96 275°C	1.318 μA	5.900nA	2.300mV	0.600mV	12.00mV	-10.40mV	4.000	-1.200
112 300°C	*2.885 μA	15.70nA	1.800mV	0.600mV	6.000mV	-12.30mV	3.700	-0.100
FINAL DATA								
FINAL TEMP (T_A)	300°C	300°C	300°C	300°C	300°C	300°C	300°C	300°C
MIN VALUE	1.510nA	420.0pA	436.0mV	323.0mV	842.0mV	622.0mV	73.90	64.00
MAX VALUE	11.90 μA	172.0nA	522.0mV	596.0mV	1.200V	1.250V	191.0	150.0
MEAN	2.931 μA	17.36nA	481.4mV	399.4mV	989.4mV	835.0mV	112.0	112.8
STD DEV	4.337 μA	45.20nA	26.30mV	68.15mV	109.9mV	159.0mV	35.93	30.02

* NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT

TABLE 7
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		U N I T S	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
	MIN	MAX			POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
					GSI	TRN	GSI	TRN	GSI	TRN
I _{CBO}	-	.1	μA		*+2.9307	*+.26614	*+2.5892	*+.04020	*+2.7457	+ .00332
V _{CE(SAT)1}	-	.6	V		+ .00050	*+.01898	+ .00082	- .07622	+ .00116	+ .01689
V _{CE(SAT)2}	-	2.5	V		- .00248	*+.08248	- .00165	+ .05863	+ .00491	*+.02910
h _{FE}	50	900	-		+10.950	*+1.5000	*+2.6260	-2.2880	+3.5429	+1.2571

* NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT



TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY

JAN TX2N4150

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	3	B	0	-
15 hr.	0	-	0	-
25 hr.	1	D	1	D
100 hr.	0	-	0	-
100 hr.	1	B	0	-
250 hr.	3	B	0	-
150% 10 hr.	JOB STOPPED		0	-
15 hr.			0	-
25 hr.			0	-
100 hr.			2	B
100 hr.			1	B
250 hr.			0	-
175% 10 hr.			1	1 C E
15 hr.			1	A
25 hr.			0	-
100 hr.			0	-
100 hr.			0	-
250 hr.			0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75°C	0	-	0	-
100°C	1	A	0	-
125°C	0	-	0	-
150°C	1	B	0	-
175°C	0	-	0	-
200°C	1	A	0	-
225°C	1	B	0	-
250°C	0	-	0	-
275°C	2	B	0	-
300°C	0	-	1	F

NOTES: A - $h_{FE} < 25$ B - $I_{CBO} > 10 \mu A$ C - $V_{CE(SAT)1} > .9V$; $V_{CE(SAT)2} > 3.75V$ D - $V_{CE(SAT)1} > .9V$

E - Notes A and B

F - Notes A and C

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	1	B	0	-
175°C	2	B	0	-
200°C	2	B	0	-
225°C	1	B	1	D
250°C	0	-	0	-
275°C	0	-	0	-
300°C	1	B	0	-

MFR "A" - GENERAL SEMICONDUCTOR, INC.

MFR "B" - TRANSITRON



TABLE 9 STEP STRESS Parametric FAILURE SUMMARY

JAN TX2N4150

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	1	A	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	1	A	0	-
100 hr.	0	-	0	-
100 hr.	1	A	0	-
250 hr.	1	A	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	1	F	0	-
100 hr.	3	A	0	-
100 hr.	4	A	0	-
250 hr.	0	-	0	-
150% 10 hr.	JOB STOPPED		1	A
15 hr.			2	A
25 hr.			0	-
100 hr.			1	A
100 hr.			1	A
250 hr.			1	G
175% 10 hr.			0	-
15 hr.			1	H
25 hr.			0	-
100 hr.			0	-
100 hr.			1	A
250 hr.	↓	↓	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75°C	1/1	A/B	0	-
100°C	0	-	0	-
125°C	0	-	0	-
150°C	1	A	0	-
175°C	0	-	0	-
200°C	1/1	A/C	0	-
225°C	1	A	0	-
250°C	0	-	0	-
275°C	0	-	0	-
300°C	2	A	1/3	A/D

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T _A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	4	A	0	-
175°C	0	-	0	-
200°C	2	A	0	-
225°C	1	A	0	-
250°C	0	-	0	-
275°C	0	-	1	E
300°C	0	-	1	A

MFR "A" - GENERAL SEMICONDUCTOR, INC.

MFR "B" - TRANSITRON

NOTES: A - I_{CBO} limit failure

B - S/N 9435 removed from testing as MIL-S-19500 failure

C - S/N 9434 removed from testing as MIL-S-19500 failure

D - S/N 9486, 9493, 9495 removed from testing as visual rejects due to handling

E - S/N 9500 removed from testing as visual reject due to handling

F - S/N 9416 removed from testing as MIL-S-19500 failure

G - V_{CE(SAT)}1 maximum limit failure

H - h_{FE} maximum limit failure



JANTX2N4150

APPENDIX

FAILURE ANALYSIS



JANTX2N4150

FAILURE ANALYSIS

Date 15 December 1978

J/N 2CN242-06A P/N 2N4150 MFR GENERAL SEMICONDUCTOR, INC.

S/N	BV _{CEO} -volts-	BV _{CBO} -volts-	I _{CBO} -μA- @ V _{CB} = 80 V.	BV _{CBO} -volts-	h _{FE} @ I _C = 1.0A; V _{CE} = 5 V.	V _{BEO} -volts- @ I _{BEO} = 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ FOR	End Pt. (Max) 0.9V
									V _{CE(SAT)} @ I _C = 5A I _B = 500mA (volts)
9421	140(H) (Uns) @2.5mA	300(Inv) (Uns)	<100nA	6.6	60	0.65	23 (125% MRP 1050 Hrs.)	V _{CE(SAT)}	0.97
9426	100(D) (Inv)	250(Inv)	35μA (D) (Inv)	10.6 (uns)	70	0.64	19 (125% MRP 1010 Hrs.)	I _{CBO}	0.80
9428	72(H)	R→250 @7nA	500μA	6.3	112	0.68	19 (125% MRP 1010 Hrs.)	I _{CLO}	0.65

INTERNAL VISUAL INSPECTION

S/N 9421 shows evidence of aluminum melting (see Figure A-1).

S/N 9426 has no significant visual defects.

S/N 9428 has oxide pinholes which bare the emitter-base junction (see Figure A-2).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable



JANTX2N4150

FAILURE ANALYSIS

Date 15 December 1978

J/N 2CN242-06A

P/N 2N4150

MFR

TRANSITRON

End Pt.:
10 μ A
Max.End Pts.:
25-1350End Pt.:
0.9V
Max.

S/N	BV _{CEO} -volts-	BV _{CBO} -volts-	I _{CBO} - μ A- @ V _{CB} = 80 V.	BV _{EBO} -volts-	h _{FE} @ I _C = 1.0 A; V _{CE} = 5 V.	V _{BEO} -volts- @ I _{BEO} = 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ FOR	V _{CE(SAT)} @ I _C = 5A, I _B = 500mA (volts)
9468	170	186	<100nA	13.0	84	0.64	23 (125% MRP 1050 Hrs.)	V _{CE(SAT)}	1.5
9477	118	198	<100nA	12.4	111 V _{CEO} =	0.65 0.65	45 (175% MRP 2025 Hrs.)	V _{CE(SAT)}	1.1
9480	R+38	120(R) (Uns)	140 μ A	R+13 (300 μ A)	60	0.64	45 (175% MRP 2025 Hrs.)	I _{CBO}	0.7

INTERNAL VISUAL INSPECTION

S/N 9468 has an area of emitter metallization which shows evidence of melting (see Figure A-3).

S/N 9477 has no significant visual defects.

S/N 9480 has a cracked die (see Figure A-4).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable



CONCLUSION

The General Semiconductor samples all have surface inversions and leakage due to contamination. The bare junction areas on S/N 9428 and the extremely high temperature experienced by S/N 9421 contributed to the contamination vulnerability of those samples.

There is a voltage threshold on these parts where the inversion and drift of I_{CBO} is triggered. Once begun, the leakage continues to increase over many seconds. This trigger voltage and slow increase in leakage explains why S/N 9421 passed the I_{CBO} test at 80 volts.

S/N 9477, which is rejectable for high $V_{CE(SAT)}$ has low resistance contacts to emitter, collector and base. The high saturation voltage must then be due to changes in bulk silicon such as an increase in base resistivity caused by migration of gold under the heat and bias of the stress test.

S/N 9480 has a cracked die.

ORIGINAL PAGE IS
OF POOR QUALITY

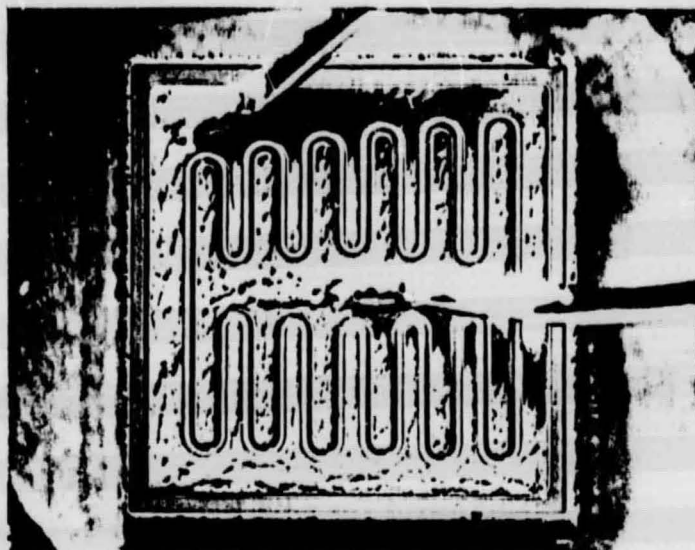


FIGURE A-1
S/N 9421, General Semiconductor, 29X.
This sample exhibits evidence of
melted metallization.

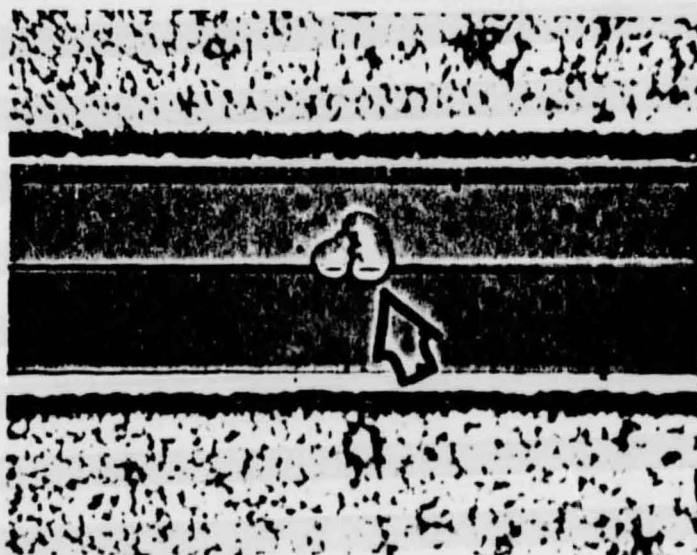


FIGURE A-2
S/N 9428, General Semiconductor, 400X.
The arrow indicates an oxide hole which
bares the emitter-base junction.

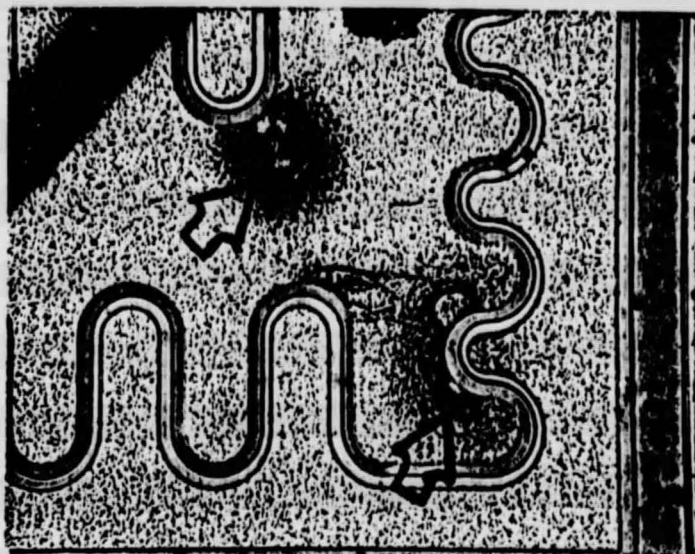


FIGURE A-3
S/N 9468, Transitron, 80X.
The arrows indicate areas of melted
aluminum metallization.



FIGURE A-4
S/N 9480, Transitron, 29X.
Arrow indicates cracks in silicon die.

ORIGINAL FILED IN
OF RECORDS